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Review

Sustainability of Urban Infrastructures

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Abstract: The scope of the paper is to overview the different approaches for evaluation of urban infrastructure sustainability. In this context, urban infrastructure covers transportation, energy, water, sewage and information networks as well as waste management and blue-green infrastructure, in terms of both the supply and demand side. A common effort of partners in the European project "C8—Best Practice in Sustainable Urban Infrastructure", developed under the Cooperation in Science and Technology program (COST), in brief COST C8, was focused on defining the methods, indicators and criteria for evaluation of sustainability, and resulted in a guidebook for decision-makers in local authorities. Here, the COST C8 matrix for simple sustainability assessment of urban infrastructure is applied to The Path (POT) case—a circular memorial and recreational park around the city of Ljubljana, Slovenia. The applicability and acceptance of the matrix in 43 other cases of sustainable urban infrastructure, collected in the COST C8 project, is presented and discussed.

Keywords: sustainability; indicators; urban infrastructures; assessment; matrix

1. Introduction

Various urban projects contribute to the development of urban infrastructure. They encompass a very broad group of projects, covering urban planning, urban design and architecture, transport studies,

economics, ecology, geography, sociology, water management and engineering, waste management, energy engineering and economics, landscape planning and building architecture. The municipalities need methods and tools for evaluating project sustainability. It is important for decision-makers at a local level to achieve a common understanding on sustainability and related criteria for decision-making in urban planning and design dealing with infrastructure. Thus, the communities create the arguments for sustainable decisions and initiate long-term benefits from saving non-renewable resources and creating more economic, sound and livable communities.

The effort of researchers in the provision of sustainability evaluation criteria applicable at the municipal level was joined in the European project "C8—Best Practice in Sustainable Urban Infrastructure" developed under Cooperation in Science and Technology program (COST), in brief COST C8 [1]. The result of the project was a book summarizing the questions, methods and tools for assessing sustainability of the development of urban infrastructure and presenting 43 different good practice cases from 15 EU countries and Canada. The book is a basic information source for planners and designers, civil servants and developers, decision-makers and lay-people dealing with urban development when assessing the sustainability of different alternatives of infrastructure.

2. COST C8 Methods for Sustainability Assessment

2.1. Background and Aims

Urban areas are growing fast and, consequently, the urban infrastructure has to meet rapidly increasing users' needs. Technical infrastructure, like transportation, energy, water supply, sewage and information networks, represents the skeleton of a city. It provides the end-users with materials, energy and information. However, on the other hand, urban infrastructure has broad and long-term impacts on sustainable development of the area. COST C8 action focused on identification of methods and tools to assess sustainability in the above cases. Primarily, the task was to define the possible indicators of urban infrastructure sustainability. Apart from the well known Brundtland definition of sustainable development, where sustainable development is seen as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [2], it has been commonly accepted that sustainable urban infrastructure focuses on prevention of unnecessary consumption of natural resources (especially non-renewable ones) and mitigation of harmful emissions. Moreover, in accordance with The Triple Link Sustainability model [3], every project may be evaluated in terms of environmental, economic and social aspects of sustainability [4], where integration and optimal balance of all three dimensions and objectives is needed for overall sustainability (Figure 1).

The research within the COST C8 project covered a broad scope of urban infrastructure sustainability, *i.e.*, all three dimensions—social, environmental and economical; infrastructural projects on local, regional and global levels; and besides the analysis of methods and tools and good practice cases, it reflected also to a theory of evaluation. The urban infrastructure was understood as a technical and social one. The technical (physical) infrastructure includes different technical networks needed for transportation of water, energy, materials, people and information, together with the related production plants and demand side conditions. Blue-green infrastructure (parks, gardens, water areas) and buildings (as the final part of the network) are also considered here. Social infrastructure covers

various services defining the relations between stakeholders. The focus of COST C8 research is oriented rather at technical infrastructures than at social ones, and it primarily covers local projects with emphasis on environmental issues (Figure 2).

Figure 1. Three basic dimensions of sustainability, needed to be considered to attain overall sustainability of an urban infrastructure project (adapted from [3]).

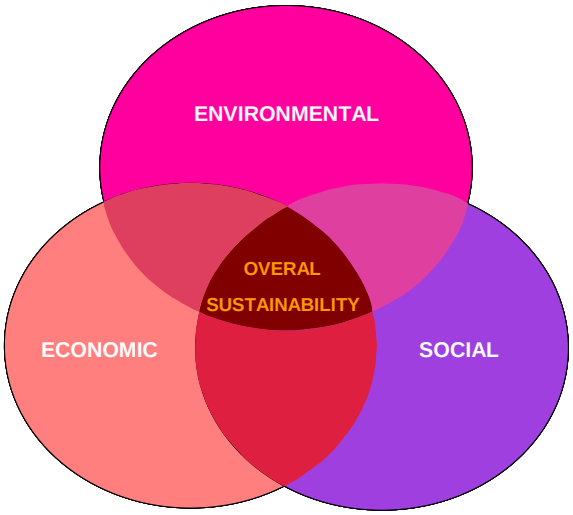
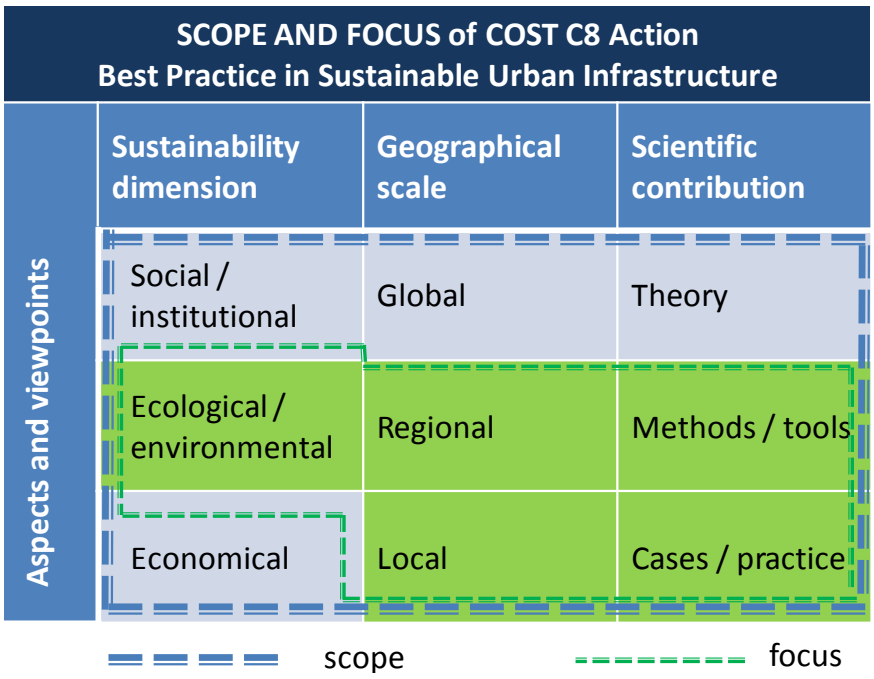


Figure 2. Scope and focus of "best practice in sustainable urban infrastructure" in COST C8 (adapted from [4]).



2.2. Assessment Methods and Tools

A large number of methods and tools are available for sustainability assessment of urban infrastructure projects. The tools vary in the scope and content, in the way they measure the indicator values, and in the presentation and interpretation of results. Most of the tools are specific with respect

to the above-mentioned categories of urban infrastructure projects (water, blue-green, transport, buildings, holistic urban infrastructure).

A number of studies focus on the comparison of methods and tools for sustainability assessment of buildings and neighborhoods, some methods cover all three sustainability dimensions [5-8], while the others remain in environmental scope, like preferentially LCA (life cycle analysis) based tools [9,10]. Braid [11] argues the inclusion of user performance criteria in the sustainability assessment tool in order to cover the social dimension of building sustainability. Some methods can be characterized as qualitative assessment methods (indicators are evaluated qualitatively with the associated subjective aspects) while the others are quantitative (based on measuring and calculating of indicators values [12]).

Sustainability assessment methods for urban infrastructures other than buildings are frequent but still less numerous than the building related methods. A planning tool for sustainability assessment of infrastructure, land-use, environment and transport is reported by Yigitcanlar and Dur [13], who also stressed that on the theoretical front the indicators should represent all sustainability domains, but on the practical front the indicators should have appropriate parameters that would make assessment possible. Several barriers (organizational, technical and external) hindering the penetration of sustainability assessment of urban transport to the local authority level in the UK were summarized by May [14]. Tweed and Sutherland [15] presented a new approach for the assessment of sustainable urban projects by the introduction of indicators for the successful integration of built heritage in urban environment projects, as this is an aspect with growing importance in our society. Many approaches to sustainability assessment of water infrastructures originate from the Dutch practice, like indicators for assessment of wastewater treatment systems [16] and an assessment of urban water systems with a focus on different human perceptions of sustainability [17]. A set of criteria for sustainable urban water management is presented in a Swedish research [18] stressing that for practical use the criteria had to be concise and related to easily measurable and quantifiable indicators.

Basic assessment methods with an environmental focus appropriate for urban infrastructure evaluation were summarized in the COST C8 project (see Table 1) together with the methods with an economic and social focus. The COST C8 study gives a brief description of each method and comments on strengths and weaknesses. The aim of these methods is the determination and evaluation of a set of indicators most commonly used in sustainability assessment.

In the investigation, it was concluded that the methods in Table 1 show diverse degrees of suitability for a comprehensive assessment of sustainability, in terms of the scope and phase of the project (planning and design *vs.* project in operation). Some methods are more appropriate for project appraisal (e.g., EIA), others are meant to deal with strategic policy decisions (SEA). Some methods are specific for a particular type of economic, social or environmental analysis, while others allow a more integrated appraisal.

LCA and EF seem to be the most commonly used methods when the environmental element of sustainability is the focus; several examples of the use of LCA in urban infrastructure projects are available (in building and the site use sector [9,10]), as well as examples of use of the EF method in energy supply infrastructure projects [19] or in holistic urban sustainability cases [20]).

Table 1. Assessment methods for sustainable urban infrastructure evaluation (adapted from [3]).

Methods with an environmental focus
Environmental Impact Assessment (EIA)
Strategic Environmental Assessment (SEA)
Life Cycle Analysis (LCA)
Ecological Footprints (EF)
The Ecological Rucksack (ER)
The Green Poster (GP)
Methods with an economic focus
Cost-Effectiveness Analysis (CEA)
Cost Benefit Analysis (CBA)
Multi-criteria decisions aid (MCDA)
Environmental Accounting (EA)
Methods with a social focus
Social Impact Assessment (SIA)
Socio Economic Impact Assessment (SEIA)

The use of conventional economic assessment methods (CEA, CBA) with respect to the definition of cost and benefits of urban projects is discussed in [21]. As long as the impacts of the evaluated project can be valued economically, aforementioned conventional assessment methods may be used. Some impacts of the project may not be easily expressed in monetary terms and in such cases multi-criteria analysis (MCA) offers a complementary approach, which facilitates decision-making. MCA may lead to determination of the importance of particular elements and indicators by introducing weighting. Multi-criteria decision analysis (MCDA) is a kind of MCA, adapted to complex projects with monetary and other objectives, and it allows the appraisal of the project by breaking it into smaller pieces and then reassembling it to a final result for decision makers. MCDA is an important method for planning sustainable urban projects [22]. Some examples of MCA use for the evaluation of projects from the energy infrastructure sector are given in [23] and for projects in green-blue infrastructure cases in [24].

The sustainability assessment methods that focus on the social elements of sustainability are less frequent than the ones with an environmental or economic focus. However, Carrera and Mack [25] report on the sustainability assessment of energy technologies via social indicators, while Begic and Afgan present a sustainability assessment tool for selection of energy systems, covering all three sustainability elements [26].

COST C8 also initiated a comprehensive in-depth survey of the evaluation tools for urban sustainability elaborated in the 5th Framework Programme project “The Practical Evaluation Tools for Urban Sustainability” (FP5 PETUS) [27-29]. Over 150 tools for sustainability assessment of urban projects were identified in PETUS. Tools for assessment of urban infrastructure sustainability that have been identified and described within the PETUS project came from two main sources: tools used within the case studies and tools identified from a literature review. The tools focus on different levels relevant for urban sustainability: building components, buildings, neighborhoods, city and regional level, and may cover one or more sectors: waste, energy, water, transport, green-blue infrastructure as well as building and land use. Each tool is presented in respect to the sector of use and scale of

application, as well as with further information about accessibility, status of maintenance and costs of the tool.

The results of the PETUS research project are presented as a website tool [28] for municipal actors who are involved in, or affected by, building and infrastructure to consider impacts on the environment, society and the economy. The website includes information that can be used to analyze and improve the sustainability of urban infrastructure. The PETUS project contributes to bridge the existing gap between theoretical frameworks and practical approaches applied in everyday practice to evaluate urban sustainability when building and managing urban technical infrastructure.

2.3. Criteria for Selection of Methods and Indicators

There is no single, most appropriate method to deal with a specific case study; different methods may be chosen. The choice of the method depends on many criteria; in practice, these include material and financial resources and staff expertise. The above mentioned methods for sustainability assessment differ intensively in the complexity and in the number of indicators.

Usually, during transition from the theory to sustainability assessment in practice, the problem is to reduce the number of sustainability indicators used in assessment. This is important to make a method feasible in practice and to increase the acceptance of the method by local actors involved in planning and decision-making of urban infrastructure projects. The local actors may use one of the existing sustainability assessment methods and tools, but this is more likely in cases of assessment of buildings and more difficult in cases of sustainability assessment of urban infrastructure projects. The local decision makers may become inspired when surveying the existing methods, tools and indicators, but often a tailored approach for assessment based on locally relevant priorities is developed.

The COST C8 study gives a list of tips for selecting relevant indicators for a particular project, such as importance and relevance of the indicator for the project considered in the local context, available time and human resources and data for calculation of indicators, potential availability of the indicator due to the regulatory provisions, uncertainty of the indicator obtained, relevance of the indicator for comparison across time and geographical area. Some indicators, e.g., CO_2 emissions, have gained a common relevance in the EU context. In most cases, indicators are aggregated and weighted by one of weighting techniques (*i.e.*, distance to target methods, economic methods or consensus based method).

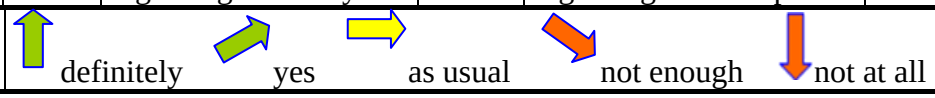
Other studies dealing with the selection of sustainability indicators for the purpose of simplification of the method recommend also the use of qualitative rather than quantitative indicators [12], and in relation to the data availability and quality, indicators should be as few as possible, but no essential indicators may be omitted, as discussed by Yigitcanlar and Dur [13]. In addition, the same authors draw attention to the problem that most indicator-based approaches only highlight issues and do not provide reasons for different sustainability levels from case to case.

The aim of the COST C8 project was to assess the sustainability of the urban infrastructure cases that were provided by local actors and understood in the local framework as sustainable projects. Due to the limited availability of data to be used in sustainability assessment (no additional studies were possible), the project team developed a simplified approach. The COST C8 sustainability assessment matrix was developed.

3. COST C8 Sustainability Assessment Matrix

Due to the need of a holistic assessment of sustainability in case of 43 urban infrastructure case studies [29] an assessment matrix (Figure 3) was developed [30]. The number of indicators in the three sustainability areas is reduced and limited to qualitative indicators. The aim of the matrix was to correspond to a need for evaluating many dimensions and many impacts of sustainability, as well as to cover the most relevant aspects in a compact space. The matrix uses verbal and visual information and allows additional explanation to the colored arrows indicating the direction and strength of the approach to sustainability. This tool is suggested as a practical way to assist infrastructure planners and decision-makers in assessing different alternatives, taking into consideration the limited time and budget available for supporting daily decisions. The "key questions" represent preliminary ideas of the areas where to find perhaps the most relevant indicators of sustainability.

Figure 3. The Assessment Matrix Model developed in COST C8 Action for rapid assessment of alternative solutions of urban infrastructure (adapted from [30]).

Ecology		**Economy**		**Social aspects**	
Are emissions to air, water and soil within the restrictions set locally and internationally? Are the emissions decreasing?		Is the cost/effectiveness and/or cost/benefits of the system reasonable compared to other systems? Compared to other needs in the city and to political goals?		Has the planning and decision-making for the infrastructure system been done in a democratic and participative way?	
Is the use of natural resources reasonable compared to other comparable systems? Is the use decreasing? (e.g., water, land)		Are the citizens willing to pay for the services offered? Are the services affordable to all citizens?		Is the function and the consequences of the system transparent to and accepted by the citizens? Is the system promoting a responsible behavior by the Citizens?	
Is the system allowing a reasonable bio-diversity with regard to the kind of area studied? Is the bio-diversity increasing?		Is the organization(s) that finance, maintain and operates the system effective?		Is the system safe to use for the citizens? (hazards, health, well-being)	
Is the system more or less sustainable than a conventional system regarding ecology?		Is the system more or less sustainable than a conventional system regarding economy?		Is the system more or less sustainable than a conventional system regarding social aspects?	
Legend	 definitely yes as usual not enough not at all				

In most cases from urban practice there is no possibility for the extensive research and data collection analysis that would additionally support the answers to the questions in the matrix. The alternative solution is to create a panel of experts and stakeholders at the local level and to use the matrix interactively according to Delphi method. In such a case, an assessment is based on existing knowledge. However, the formation of expert panels is a sensitive step of the assessment process, as the variety of local opinions has to be represented in the panel.

The arrows with specific questions represent the possible options (as given in the legend) to be chosen during the assessment process. The questions and answers converted into the arrows with different orientations are independent, but at the end of each column aggregated to give the response to the summary question, *i.e.*, aggregated indicator of particular sustainability element.

4. Good Practice Cases of Sustainable Urban Infrastructure

4.1. Variety of Cases

The aim of collecting the case studies in COST C8 was to explore the ways in which sustainability projects are realized in practice and to demonstrate the type of applications already in use throughout Europe. The criteria for selection of cases were: the case study is considered as sustainable and well accepted in the local environment, an adequate geographical coverage of cases in COST C8 countries, a balanced number of cases in each field of sustainable urban infrastructure, a contact to the local team (investor, stakeholders, experts) for further information, willingness of the local actors to participate in assessment according to the simplified matrix, the evaluation of sustainability should be as much as possible based on existing scientifically valid information, the possibility to access the case study by reference to environmental, economic, social and institutional barriers.

The collection of case studies is aimed at urban planners and engineers, stakeholders and all others who are involved in the decision-making processes associated with initiating sustainable development in the urban context. The cases are distributed in six categories (Table 2). Each case study is described by general presentation, most important indicators of environmental, economic, social sustainability, by initial self-assessment, benchmarks and lessons learnt. The more objective part in the presentation is the application of the simplified matrix where appropriate, due to the nature of the case study. The matrix could be applied by a COST C8 participant in support to the local project team or *vice versa*.

Table 2. Cases of sustainable urban infrastructure collected and assessed in COST C8 (adapted from [29,30]).

GREEN/BLUE
Rever (Reseau vert europeen/european green network) crossing—Brussels, BELGIUM
Rennes Urban Greenspace Differentiated Management, FRANCE
Green Poster Fredrikstad, NORWAY
Stockholm's Green Infrastructure, SWEDEN

Table 2. *Cont.*

TRANSPORT
Urban space zoning, AUSTRIA
Lyon Urban Mobility Master Plan, FRANCE
Meckenheim's Motto: Interference wanted, GERMANY
The re-organization of the railway system in the Florentine metropolitan area, ITALY
Ecosystem fragmentation assessment for the Trento-Rocchetta road project, ITALY
Buga, the free riding bicycle of Aveiro, PORTUGAL
The mobility program as the link of the interventions of Porto 2001—Baixa District, PORTUGAL
Escalators to access Toledo's Historic Core, SPAIN
City of Zurich, SWITZERLAND
ENERGY
Vienna Climate Protection Programme, KLIP, AUSTRIA
The Christophorus House—a multi-purpose office building with low-energy consumption, AUSTRIA
Middelgrunden Windfarm, DENMARK
Tervola Small Scale CHP Bio Energy Plant, FINLAND
Two million marks for Da Di, GERMANY
The Emporium Case, NETHERLANDS
Green Municipality, Green Electricity, NETHERLANDS
City District Heating and Cooling, NETHERLANDS
Supporting sustainable choice of energy efficient windows, SLOVENIA
WATER/SEWERAGE
The Kolding Pyramid, DENMARK
Digital diagnostics system for sewer pipes, FINLAND
Storm water management "Porte des Alpes" site in the Lyon suburbs, FRANCE
Sustainable Housing Estate Eva-Lanxmeer, NETHERLANDS
The sustainability of conventional *versus* nature based sewerage systems, NORWAY
The Bromma Biogas Plant, Stockholm, SWEDEN
Separating waste water system, SWEDEN
WASTE
Strategic environmental assessment (SEA) for the Viennese Waste Management Plan, AUSTRIA
Soil remediation program, FINLAND
Pneumatic Waste Collection, SPAIN
Construction Waste Minimization, UK
HOLISTIC
Urban ecological renewal of the Hedebygade Block, DENMARK
Viikki Eco Neighborhood Blocks, FINLAND
Ferrara—the Children's city, ITALY
ECUB project (rehabilitation of an veterinary school into an urban "Eco-centre", Brussels, BELGIUM
Rehabilitation and restoration of Skocjanski Zatok, SLOVENIA
The Path (POT)—a circular memorial park around Ljubljana, SLOVENIA
Urban renewal and social insertion: the opening of the city to the sea, SPAIN, (plus Portugal)
ASSESSMENT
The use of checklists to support spatial planning in Graz, AUSTRIA
Radiation solar comfort early analysis in high density urban context, BELGIUM
Energy and Environmental Prediction Model, UK

4.2. Application of Assessment Matrix on a Holistic Urban Infrastructure Case Study

In many case studies the COST C8 assessment matrix was successfully applied. In some cases the matrix was not fully applicable due to the lack of data or due to the major deviation from the envisaged scope of urban infrastructure project. An example of a holistic case is presented in Figure 4, describing the infrastructural project "The path (POT)" [31]. The project is located in Slovenia and it covers the construction of a circular memorial park around the city of Ljubljana, bringing into a circle individual natural landscape features and green areas in the city. The path offers over 40 km of sports routes (walking, running, cross-country skiing, recreational cycling, relaxing in nature), it acts as an area of significant environmental value and maintains a historic memory of a World War II Ljubljana, occupied and entirely fenced in by barbed wire.

Figure 4. A holistic case of sustainable infrastructure "The path (POT)", Slovenia [31], describes a circular memorial park around the city of Ljubljana, Slovenia.

The assessment matrix was used by the members of the local authority responsible for the POT project (Figure 5). The local authority members were assisted by external experts and by national member(s) of COST C8 project. Also, the stakeholders' values were integrated in the POT project team as much as possible; partly by having core decisions within the local authority taken by the democratically elected city councilors that are responsible for decisions to their voters (stakeholders) and partly by public consultations with stakeholders implemented during the planning process based on the principle of Aarhus convention [32]. The answers to the questions in each sustainability field column were provided by Delphi method. The goals and priorities of local authority, stakeholders' aims, and external experts' knowledge were represented in the expert panel for assessment of the above case study. The assessment was completed after the second panel meeting. The results obtained in the matrix demonstrated a favorable perception of sustainability of the memorial circular "the Path (POT)" around the city.

Figure 5. Assessment of sustainability in the case of "The path (POT)" urban infrastructure project (Figure 4), using the COST C8 assessment matrix.

Ecology		**Economy**		**Social aspects**	
Emissions?		Cost/effectiveness and/or cost/benefits?		Participation in decision making?	
Use of natural resources?		Willingness to pay?		Transparency?	
Bio-diversity?		Effective organization?		Safety?	
Is the system more or less sustainable than a conventional system regarding ecology?		Is the system more or less sustainable than a conventional system regarding economy?		Is the system more or less sustainable than a conventional system regarding social aspects?	

The assessment matrix was demonstrated during the sustainability evaluation of case studies, in which the drivers for the sustainable urban infrastructure projects were in most cases environmental, only in the holistic cases there was a strong influence of social aspect. In general, during the testing of the matrix on case studies a need for additional comparable and reliable benchmarking data was expressed in order to facilitate the judgment in particular aspects. Additional qualitative benchmarks in the matrix may improve the quality of sustainability assessment, but on the other hand, the simplicity of the COST C8 matrix method contributes to its potential for application in real life, where the local authorities face very tight timetables and budget constraints and may, on the other hand, use the application of the matrix to promote more sustainable approaches in planning of urban infrastructure at a local level.

One of the important conclusions of the COST C8 project referred to the need for a more structured sustainability evaluation method for the urban infrastructure projects, flexible enough to accommodate different types of cases, allowing combination of quantitative and qualitative methods as appropriate and covering all three aspects of sustainability. This complex task later became a core idea of the FP5 PETUS project inventory of methods and tools for urban infrastructure assessment.

5. Discussion and Conclusions

COST C8 action aimed at identifying and comparing several sustainability assessment methods for urban infrastructure projects. It also provided a simple sustainability assessment matrix to be used for rapid evaluation in decision-making processes at a municipal level. Due to the constraints of the COST C8 project, *i.e.*, limited time and a very low budget, the participation of project members in the design phase and in decision-making was not possible; therefore the matrix was tested in a post-evaluation of 43 sustainable urban infrastructure case studies. Using the matrix during the planning process would increase the chances of the project team to get additional studies approved (complementing the ones foreseen by the regulation) as well as to get expert support to help provide

answers for more technical issues, and thus improve the quality of sustainability assessment. Where monitoring of the urban infrastructure in operation is not established, the assessors are far more limited in evaluation.

In general, the assessment matrix was applied by the local authority members involved also in the project development, by the help of external experts offering assistance to the local authority staff, by COST C8 national members, and taking stakeholders' opinions and values into consideration. When assessment is via a qualitative method there is a risk of subjective judgment; this can be reduced by applying Delphi method. Therefore, it is important to create the assessment expert group in a way that all stakeholders' opinions and key actors (with expert knowledge support) are involved. The integration of stakeholders' opinions and expectations is not an easy process, but on the other hand it of growing importance due to the societal culture and political commitment of the city councilors to specific interest groups.

The cases from categories: green-blue infrastructure, transport, energy, water/sewage, waste and holistic were sufficiently compatible with the assessment matrix, while the cases from the assessment category (*i.e.*, simulation model, software, and tool) had a different scope and therefore did not fit into the assessment matrix. In 13 cases, the stakeholders easily fulfilled the matrix and transduced it in the presentation of the case studies. In 18 cases, only the summary opinion about environmental, economy and social aspect of sustainability (the last row in the matrix) was reported, while the detailed description of aspects was too vague to describe, due to the lack of necessary data and relevance of the questions to the case study, respectively. 12 case studies did not include the sustainability assessment matrix, most frequently because the presenters of the case studies felt that the existing form of presentation gives a more comprehensive overview of the sustainability than the matrix may provide.

A lesson learnt from the COST C8 assessment efforts was that in the case of evaluating existing urban infrastructure projects the necessary information was not always available or the data about the project were not explicit enough to allow a reliable use of the assessment matrix. As the collected cases were only subject to post-evaluation here, the provision of additional data and in-depth seeking for comparable and measurable indicators could not be fully realized. The assessment method should demonstrate a reasonable ratio between the number of indicators and the complexity of the analysis on one side and the effort of assessors and project team in the other side. Too intensive simplification leads to a loss of information and credibility, as it was commented during the testing phase.

This barrier may be reduced if an upgrade of the sustainability assessment matrix with some questions specific to the particular case in the local environment is done. Delphi method allows some modifications of questions during the assessment process. This approach can be implemented if the matrix is used in the planning process of a particular case and not in the post-evaluation for comparison of various cases.

When evaluating the rate of successful implementation of the matrix, one cannot disregard the fact that the application was highly encouraged, but was still implemented on a voluntary basis. Other success factors for better introduction of sustainability assessment tools into planning and decision-making processes are: growing interest for sustainability, binding targets for public sector expressed in green procurement rules [33], voluntary environmental labeling, free-term agreements on environmental issues (like commitments under the Covenant of Mayors initiative [34]), changes of

stakeholder values, changes in planners' and designers' remuneration policies in order to stimulate sustainable solutions, and in the future also the sustainability integrated in the regulation.

The COST C8 sustainability assessment matrix was found to be a useful tool if integrated in the decision-making process from the very beginning; as it stimulates the monitoring of sustainability at all stages of the project development and it enables the comparison of competitive alternative solutions.

6. Conclusions

In the paper, methods for sustainability assessment of urban infrastructure projects are discussed. Additional information on methods and available tools for urban infrastructure projects are presented through literature review, COST C8 and PETUS web sites. A simple tool for qualitative assessment of sustainability of urban infrastructures in the form of an assessment matrix was proposed and tested on 43 cases that were considered as sustainable in their local environments. Some barriers emerged during the use of the assessment matrix in this post-evaluation of implemented infrastructures, like the lack of data, limited budget for studies and the lack of commitment of key actors for the assessment. The researchers, as well as the actors involved in the test phase recommended the matrix for use in planning and decision-making processes in order to assess and improve the sustainability of urban infrastructure projects. The potential of the matrix for the proposed use was discussed and the success factors for the integration of sustainability assessment tools in the planning process were summarized. The described research is a useful source of information for stakeholders at the local level, as the assessment methods and tools may comprehensively support sustainable choices that are also the basis for the green public procurement of urban infrastructures.

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